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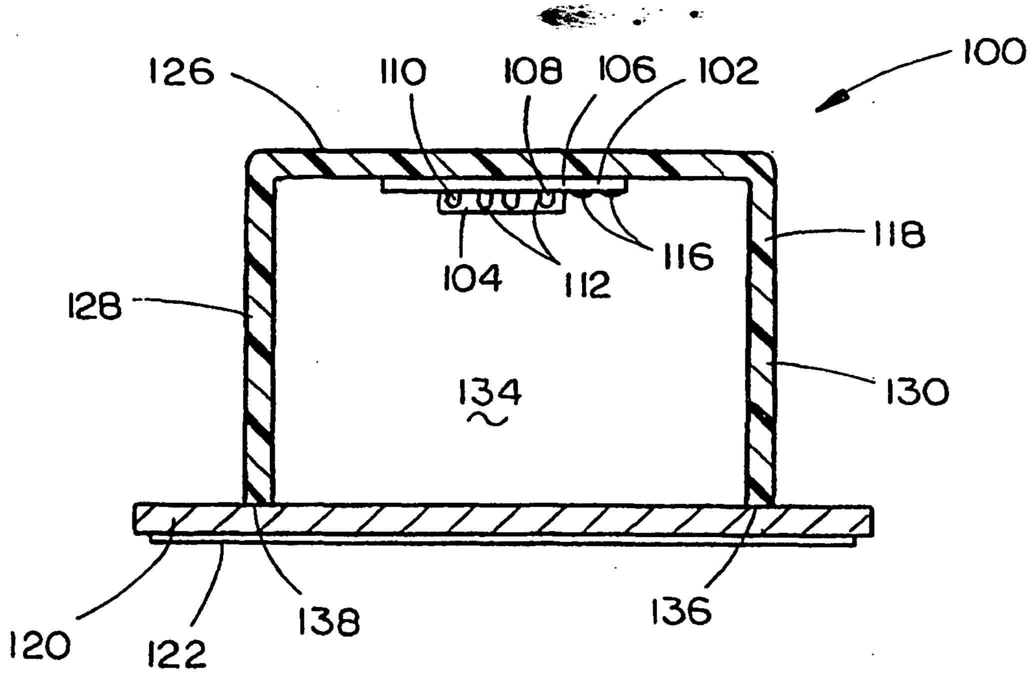
(54) Title: RFID TAG HAVING DIPOLE OVER GROUND PLANE ANTENNA



(57) Abstract

An RFID tag (100) having a dipole over ground plane (DOG) antenna is disclosed. The DOG antenna structure allows the RFID tag (100) to be placed on metal or RF absorbing surfaces and to be read over increased ranges. The RFID tag includes an RF transponder (102) for communicating with an RFID system. A base plate (120) which may be attached to a metal or RF absorbing surface forms a conducting ground plane. A support (118) is attached to the base plate and holds the RF transponder (102) so that its dipole is spaced at a distance from the conducting ground plane.

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RFID TAG HAVING DIPOLE OVER GROUND PLANE ANTENNA

Cross-Reference to Related Applications

The present application claims the benefit under 35 U.S.C. § 119 of U.S. Provisional Application Nos. 60/073,099, filed January 30, 1998; 60/076,363, filed February 27, 1998; and 60/078,292, filed March 17, 1998 and U.S. Provisional Application to Brady et al. (Express Mail Label No. EL 025 200 246 US), filed October 6, 1998. Said U.S. Provisional Application Nos. 60/073,099, 60/076,363, 60/078,292 and Provisional Application to Brady et al. (Express Mail Label No. EL 025 200 246 US) are herein incorporated by reference in their entirety.

Incorporation by Reference

The following US Patents and Patent Applications are hereby incorporated herein by reference in their entirety:

U.S. Patents

Patent No.	Issue Date	Filing Date	Attorney Docket No.
5,521,601	05/28/96	04/21/95	YO995-0088
5,528,222	06/18/96	09/09/94	YO994-180
5,538,803	07/23/96	11/23/94	YO994-0073
5,550,547	08/27/96	09/12/94	YO994-185
5,552,778	09/03/96	11/23/94	YO994-0232
5,554,974	09/10/96	11/23/94	YO994-0071
5,563,583	10/08/96	11/23/94	YO994-070
5,565,847	10/15/96	11/23/94	YO994-0072
5,606,323	02/25/97	08/31/95	YO995-157
5,635,693	06/03/97	02/02/95	YO994-0215
5,673,037	09/30/97	09/09/94	YO994-184
5,680,106	10/21/97	10/27/95	YO995-0219
5,682,143	10/28/97	09/09/94	YO994-170
5,729,201	03/17/98	06/29/95	YO995-109

Patent No.	Issue Date	Filing Date	Attorney Docket No.
5,729,697	03/17/98	04/24/95	YO995-076
5,736,929	04/07/98	06/07/96	YO996-085
5,777,561	07/07/98	09/30/96	YO996-178

U.S. Nonprovisional Patent Applications

Application No.	Filing Date	Attorney Docket No.
08/681,741	07/29/96	YO996-037
08/660,249	06/07/96	YO996-084 (allowed 4-28-98)
08/621,784	03/25/96	YO996-031
08/626,820	04/03/96	YO995-158
08/646,539	05/08/96	YO996-068
08/681,741	07/29/96	YO996-037
08/694,606	08/09/96	YO995-218
08/790,639	01/29/97	YO997-024
08/790,640	01/29/97	YO997-023
08/733,684	10/17/96	YO996-195
08/862,149	05/23/97	YO997-116
08/862,912	05/23/97	YO997-115
08/862,913	05/23/97	YO997-114
08/909,719	08/12/97	YO995-109B (allowed)
08/935,989	10/23/97	YO997-310

U.S. Provisional Patent Applications

Application No.	Filing Date	Attorney Docket No.
60/073,102	01/30/98	YO897-0028P1
60/074,605	02/13/98	YO897-0259P1
60/077,879	03/13/98	YO997-0038P1
60/078,287	03/17/98	YO897-0661P1

Application No.	Filing Date	Attorney Docket No.
60/078,304	03/17/98	YO897-0662P1
60/091,350	07/01/98	YO897-0259P2
60/093,088	07/16/98	38384P1

The following further documents are also incorporated herein by reference in their entirety:

IBM Technical Disclosure Bulletin

IBM Technical Disclosure Bulletin: Vol. 38 No. 08, August 1995, page 17, "Multifunction Credit Card Package," by Brady, Moskowitz, and Murphy (published anonymously).

Literature Reference

D. Friedman, H. Heinrich, D. Duan, "A low-power CMOS integrated circuit for field-powered radio frequency identification (RFID) tags," 1997 Digest of Technical Papers of the IEEE International Solid-State Circuits Conference (ISSCC), San Francisco, CA, February 1997.

PCT Published International Applications

Application No.	Filing Date	Attorney Docket No.
PCT/GB96/00061	01/15/96	UK 9-94-066 PCT
PCT/EP95/03703	10/20/95	YO994-242 PCT

UK Published Application

Application No.	Filing Date	Attorney Docket No.
9710025.9	05/19/97	YO9-96-084

Field of the Invention

The present invention relates generally to radio frequency identification (RFID) systems, and more specifically to RFID tags having a dipole over ground plane (DOG) antenna structure for use in RFID systems.

Background of the Invention

Radio Frequency Identification (RFID) is becoming an important identification technology in applications such as inventory management, security access, personnel identification, factory automation, automotive toll debiting, and vehicle identification to name just a few. RFID systems utilize an RFID transmitter-receiver unit (usually referred to as a base station or interrogator) to query an RFID transponder or tag which may be located at a distance from the transmitter-receiver unit. The RFID tag detects the interrogating signal and transmits a response signal containing encoded data back to the receiver.

RFID systems provide identification functions not found in identification technologies such as optical indicia (e.g., bar code) recognition systems. For example, RFID systems may employ RFID tags containing read/write memory of several kilobytes or more. The RFID tags may be readable at a distance and do not require direct line-of-sight view by the reading apparatus (e.g., base station or interrogator). Further, several such RFID tags may be read by the RFID system at one time.

Often it is desirable to place an RFID transponder on a metal or RF absorbing surface such as an automobile, truck, trailer, cargo container, steel or aluminum warehouse pallet, etc. In such applications, the transponder may suffer limitations in range due to the effect of the metal surface on the impedance of its antenna. Further, conventional transponders may be damaged by harsh outdoor or warehouse environments. Consequently, it would be desirable to develop an RFID tag using a dipole over ground plane antenna wherein the tag may be placed on metal or RF absorbing surfaces while providing increased range.

Summary of the Invention

Accordingly, the present invention provides a novel RFID tag having a dipole over ground plane (DOG) antenna structure. The DOG structure allows the RFID tag to be placed on metal or RF absorbing surfaces and to be read over increased ranges. The RFID tag includes an RF transponder configured to communicate with an RFID system. A base plate which may be attached to a metal or RF absorbing surface forms a conducting ground plane. The RF transponder includes a dipole which is held at a distance from the conducting ground plane by a support attached to the base plate. The support may comprise a housing which encloses the RF transponder to protect it from environmental contaminants.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the invention claimed. The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate an embodiment of the invention and together with the general description, serve to explain the principles of the invention.

Brief Description of the Drawings

The numerous objects and advantages of the present invention may be better understood by those skilled in the art by reference to the accompanying figures in which:

FIG. 1A is an isometric view of an exemplary RFID tag in accordance with an exemplary embodiment of the present invention;

FIG. 1B is a cross-sectional profile view of the RFID tag shown in FIG. 1;

FIG. 2A is an isometric view of an embodiment of the RFID tag wherein the support has a trapezoidal cross-section;

FIG. 2B is a cross-sectional profile view of the RFID tag shown in FIG. 2A;

FIG. 3 is a cross-sectional profile view of an embodiment of the RFID tag wherein the support has an arcuate cross sectional profile;

FIG. 4A is an isometric view of the dipole and ground plane of the RFID tag of the present invention illustrating methods of tuning the impedance of the antenna;

FIG. 4B is a side elevational view of the dipole shown in FIG. 3A;

FIG. 4C is a top plan view of the tuning snub of the dipole shown in FIG. 3A; and

FIG. 5 is a view illustrating an RFID system employing an RFID tag having a dipole over ground plane (DOG) antenna in accordance with the present invention.

Detailed Description of the Invention

Reference will now be made in detail to the presently preferred embodiment of the invention, an example of which is illustrated in the accompanying drawings.

Referring now to FIGS. 1A and 1B, an RFID tag in accordance with an exemplary embodiment of the present invention is shown. The RFID tag **100** has a dipole over ground plane (DOG) antenna structure. The DOG antenna structure allows the RFID tag **100** to be placed on metal or RF absorbing surfaces (see FIG. 5) and to be read over increased ranges compared to an RFID tag employing a tuned dipole antenna. The RFID tag **100** includes an RFID transponder **102** which is configured to communicate with an RFID system via the system's base unit or a handheld interrogator (see FIG. 5). The RFID transponder **102** preferably includes a packaged RFID integrated circuit (RFID IC) **104** including RF modulator circuits, logic circuits, and memory mounted to a substrate **106** and bonded to a dipole **108**.

Substrate materials include polyester, polyimide, ceramics, FR-4 epoxy, phenolic, and other dielectric materials. The packaged RFID IC **104** preferably comprises an RFID IC chip encapsulated within a plastic-molded package **110**. The package **110** may be a single in-line package (SIP), dual in-line package (DIP), or preferably a flat pack (shown). Typical flat pack IC packages which may be employed by the present invention include, but are not limited to, small outline packages (SOP), miniature small outline packages (MSOP), and small

outline integrated circuit (SOIC) packages. Preferably, the package **110** includes a plurality of external leads or pins **112** which are connected (as required by the IC design) to the RFID IC chip via conventional techniques (such as wire bonding or the like). For example, two of the leads **112** may connect the RFID IC chip to the dipole **108** formed on the substrate **106** (i.e., the leads **112** may be soldered to the dipole **108** using convention soldering techniques). Alternatively, the RFID IC chip may be directly mounted to the substrate **106** and bonded to the dipole **108**. The RFID IC chip may be coated with an encapsulant, such as a "glob-top" epoxy, or the like and/or laminated with a laminate to protect the chip (and bonds between the dipole and chip) from damage.

The dipole **108** may be integrally formed on the substrate **106**. Preferably, the dipole **108** comprises thin, typically 18 to 35 micron thick, lines formed of a conductive metal such as copper. These lines may be formed by plating, adhering or screening a thin layer of copper (or other conductive metal) onto to the substrate **106**. This layer may then be etched to form the specific geometric configuration of the dipole **108** (i.e., simple dipole, folded dipole, meander dipole, etc.). An advantage of the dipole over ground plane (DOG) antenna structure is that at a suitable standoff distance (see FIG. 4A), such as about 7 percent to 11 percent of a wavelength, the radiation resistance of a resonant dipole (about 73 ohms) is reduced to a lower value (i.e., about 10 ohms). Preferably, this lower resistance value is close to the resistance of the RFID IC **104** providing a good starting point for impedance matching which may be perfected by other impedance adjustment elements (i.e., tuning stubs, loading bars, impedance matching circuits, etc.). One or more such impedance adjustment elements may be integrally formed on the substrate **106** to modify the impedance of the dipole **108**. The impedance adjustment elements may be lumped circuit elements, distributed microwave circuit elements, or a parasitic element that is electromagnetically coupled to the dipole **108** (i.e., not electrically connected). For example, the dipole **108** may include a tuning stub **114** having a length and width adjusted to tune the impedance of the dipole

108. The tuning stub **114** acts as a two conductor transmission line and may be terminated either in a short-circuit or open-circuit. A short circuited stub acts as a lumped inductor while an open-circuit stub acts as a lumped capacitor. The magnitude of the reactance of the tuning stub **114** is affected by the stub's length, width, and spacing. Similarly, one or more impedance loading bars **116** may be positioned on the substrate **106** adjacent to the dipole **108** so they are electromagnetically coupled to the dipole **108** to modify its impedance.

The RF transponder **102** may be "active" meaning that the transponder **102** includes an internal transmitter for transmitting information to an interrogator or base station (not shown), or "passive" meaning that the transponder uses a modulated back scattered RF field (generated by the interrogator or base station) to provide a return signal to provide the information. The RF transponder **102** may be field powered, or alternatively, may be at least partially battery powered. Field powered transponders collect power from the RF field generated by the interrogator or base station and convert the collected power to a dc voltage which is stored in a capacitor to provide power for operating the transponder's other circuitry. Battery powered transponders typically employ coin shaped battery (not shown) mounted to the substrate **110** and electrically connected to the RFID IC **104**.

While a typical RF transponder has been illustrated and described herein in connection with FIG. 1, numerous other RF transponder designs or configurations presently exist or may be developed in the future. Thus, it should be appreciated that modification or reconfiguration of the RF transponder **102** of FIG. 1 by one having ordinary skill in the art would not depart from the scope or the spirit of the present invention.

The RF transponder **102** is held by a non-conducting support **118** at a fixed distance from a base plate **120** which forms a conducting ground plane. In this manner, the dipole **108** is suspended over and held generally parallel to the conducting ground plane. Preferably, the dipole **108** is a one half wavelength (λ) dipole radiator and is suspended approximately one tenth of a wavelength (λ) above the conductive ground plane wherein the wavelength (λ)

is determined by the frequency at which the RFID system operates.

The base plate **120** which forms the ground plane may be rectangular in shape and may be attached to a metal or RF absorbing surface (see FIG. 5) via as fastener **122** such as an adhesive, double-sided tape (shown), rivets or bolts (via holes **124**), hook and loop fastener material, or the like. When attached to the metal or RF absorbing surface, the bottom of the base plate **120** abuts the surface so that the RF transponder **102** is held away from the surface by the support **118**. Preferably, the base plate **120** is made of a metal (i.e., aluminum, steel, brass, titanium, copper, etc) or a metallized material (i.e., a metallized plastic, mesh, screen, etc). The base plate **120** may have dimensions (i.e., length and width) on the order of one half of a wavelength (λ) wherein the wavelength (λ) is determined by the frequency at which the RFID system operates.

The RF transponder **102** may be attached to a surface within the support **118** via a fastener such as an adhesive, double-sided tape, rivets, "snap-on" molded plastic tabs, or the like. The support **118** may be attached to the base plate **120** (via a fastener such as an adhesive, rivets, bolts, etc.) and sealed to prevent environmental contaminants from reaching the RF transponder **102**. Preferably, the support **118** is made of a non-conducting material such as polypropylene plastic.

As shown in FIG. 1B, the support **118** may comprise a hollow shell having a rectangular cross-section. The support **118** may include an outer wall **126**, first and second side walls **128** & **130**, first and second end walls **132** (FIG. 1A) & **134** and a generally rectangular open end **136** opposite the outer wall **126**. Edges **138** of the first and second side walls **128** & **130** and first and second end walls **132** (FIG. 1A) & **134** opposite the outer wall **126** are attached and sealed to the base plate **120** via an adhesive, sealant, or the like. Preferably, the RF transponder **102** is placed within the support **118** via the open end **136** and attached to the inner surface of the outer wall **126** so that it is held generally parallel to the base plate **120** and conducting ground plane. The first and second side walls **128** & **130** and first and second end walls **132**

(FIG. 1A) & **134** space the outer wall **126** and RF transponder **102** attached thereto from the base plate **120** and ground plane. Further, the RF transponder **102** is preferably sealed within the support **118** when the support **118** is attached to the base plate **120** so that the RF transponder **102** is protected from environmental contaminants.

Referring now to FIGS. 2A and 2B, an RFID tag having a support in accordance with a second exemplary embodiment of the present invention is shown. The support **202** of this embodiment of the RFID tag **200** may comprise a hollow shell having a generally trapezoidal cross-section and including an outer wall **204** parallel to the base plate **206**, opposed first and second trapezoidal end walls **208** & **210** and first and second side walls **212** & **214** extending at generally equal obtuse angles from outer wall **204**. Preferably, the side and end walls **208**, **210**, **212** & **214** form a generally rectangular open end **216** opposite the outer wall **204** wherein the edges **218** of the first and second side walls **212** & **214** and first and second end walls **208** & **210** opposite the outer wall **204** are attached and sealed to the base plate **206** via an adhesive, sealant, or the like. As with the generally rectangular support **118** (FIGS. 1A and 1B), the RF transponder **220** (which may be constructed similarly to the RF transponder **102** shown in FIGS. 1A and 1B) is placed within the trapezoidal support **202** via the open end **216** and attached to the inner surface of the outer wall **204** so that it is held generally parallel to the base plate **206** and conducting ground plane. The first and second side walls **212** & **214** and first and second end **208** & **210** walls space the outer wall **204** and RF transponder **220** attached thereto from the base plate **206** and ground plane. Further, the RF transponder **220** is preferably sealed within the support **202** when the support **202** is attached to the base plate **206** so that the RF transponder **220** is protected from environmental contaminants.

Referring now to FIG. 3, an RFID tag having a support in accordance with an alternative embodiment of the present invention is shown. The support **302** of this embodiment of the RFID tag **300** includes an outer wall **304** having an arcuate cross section and first and second semi-circular end walls **306**.

Edges **308** of the outer wall **304** and the first and second end walls **306** are attached and sealed to the base plate **310** via an adhesive, sealant, or the like. Preferably, the RF transponder **312** (which may be constructed similarly to the RF transponder **102** shown in FIGS. 1A and 1B) is placed within the support **302** and attached to the inner surface of the outer wall **304** so that it is held generally parallel to the base plate **310** and conducting ground plane. Preferably, the curvature of the outer wall **304** causes the RF transponder **312** to be held at a fixed distance from the base plate **310** and ground plane. The RF transponder **312** is preferably sealed within the support **302** when the support **302** is attached to the base plate **310** so that the RF transponder **312** is protected from environmental contaminants.

In view of FIGS 1A through 3, it should now be appreciated that supports may be provided by one of ordinary skill in the art which have wide variety of cross-sections. For example, supports may be provided which have generally triangular cross-sections, generally polygonal cross-sections, or curvilinear cross-sections. Supports having such cross-sections are anticipated by and would not depart from the scope or the spirit of the present invention

Referring now to FIGS 4A, 4B and 4C, methods of adjusting or matching the impedance of RFID tags using dipole over ground plane (DOG) antennas are illustrated. As shown in FIG. 4A, the dipole **402** of the RFID tag **400** may be mounted (as described in FIGS. 1A through 3) at a distance ("H") from a conducting ground plane **404**. Preferably, the ground plane **404** comprises a flat base plate **406** having a length ("L_g") and a width ("W_g"). As shown in FIG. 4B, the dipole **402** may have a length ("L") and a width ("W"). The dipole **402** shown is a simple dipole having two elements **408** & **410**. One or more tuning stubs **412** may be formed in either or both elements **408** & **410**. Each tuning stub **412** comprises parallel stub lines **414** & **416** extending perpendicularly from a dipole element **408** & **410**. Preferably, the stub lines **414** & **416** are generally parallel to the conducting ground plane **404**. Each tuning stub **412** acts as a two conductor transmission line and may be terminated either in a short-circuit or open-circuit (a short-circuit is shown). A short circuited stub acts

as a lumped inductor while an open-circuit stub acts as a lumped capacitor. As shown in FIG. 4C, the tuning stub **412** may have a stub line length ("L_s"), a sub line width ("W_s"), and an edge-to-edge distance or space between stub lines ("S_s"). The tuning stub **412** may be positioned along the element **408** & **410** at a distance ("X_s") from the center of the dipole **418**. One or more impedance loading bars (see FIG. 1) may be positioned adjacent to the antenna **402**. Use of tuning stubs and impedance loading bars to adjust the impedance of an antenna is described in detail in U.S. Patent Application Serial No. 08/790,639 to Duan, et al. filed January 29, 1997 which is herein incorporated by reference in its entirety.

Preferably, the impedance of the antenna **402** may be adjusted depending on the frequency of the RFID system it is to be used with by modifying at least one of the width of the dipole ("W"), the length of the dipole antenna ("L"), the distance between the dipole and the conducting ground plane ("H"), and/or the size of the conducting ground plane (i.e., the length ("L_g") and width ("W_g") of the base plate **404**). Wherein the antenna **402** includes one or more tuning stubs **412**, the impedance of the antenna may further be adjusted by modifying at least one of the width of the tuning stub (e.g., stub line width ("W_s")), the length of the tuning stub (e.g., stub line length ("L_s")), the distance of the tuning stub from the center of the dipole ("X_s"), and/or the edge to edge space between the stub lines ("S_s"). For example, an advantage of the dipole over ground plane (DOG) antenna structure is that at a suitable distance ("H"), such as about 7 percent to 11 percent of a wavelength, the radiation resistance of a resonant dipole (about 73 ohms) is reduced to a lower value (i.e., 10 ohms). Preferably, this lower resistance value is close to the resistance of the RFID IC (see FIGS. 1A through 3) providing a good starting point for impedance matching which may be perfected by other impedance adjustment elements (i.e., tuning stubs, loading bars, impedance matching circuits, etc.).

In an exemplary embodiment, an RFID tag having a dipole over ground plane (DOG) antenna structure may be configured for use in an RFID system

which operates at a frequency of, for example, 2.45 GHz. For this embodiment, the antenna of the RF transponder may comprise a dipole having a tuning stub which is etched on a standard printed circuit board mounted by an adhesive to the inside of the RFID tag's support. The RF transponder's circuit chip is enclosed in a plastic package (i.e., a small outline integrated circuit (SOIC), miniature small outline package (MSOP), etc.) which is mounted to the substrate and soldered to the antenna. Preferably, the antenna is held at a distance ("H") of approximately 10 millimeters (mm) above the base plate and has a length ("L") of less than about 50 mm and a width ("W") of approximately 0.5 mm. The tuning stub is positioned at a distance from the center of the dipole ("Xs") of approximately 10 mm and has a width ("Ws") of about 0.25 mm, a length ("Ls") of about 5 mm, and a edge-to-edge space between stub lines ("Ss") of about 0.5 mm. The base plate of the RFID tag is approximately 54 to 55 mm in width ("Wg") by 85 to 86 mm in length ("Lg"). For this configuration, the range of the RFID tag has been measured to be approximately 1.4 meters (m) which represents an increase of approximately 75 percent over the range of a comparable tuned dipole.

Referring now to FIG. 5, an RFID system employing an RFID tag having a dipole over ground plane (DOG) antenna structure in accordance the present invention is shown. The RFID system **500** includes an RF transmitter-receiver unit (typically referred to as a base station or interrogator) **502** to query the RFID tag **504** located at a distance from the unit. The interrogator **502** may be fixedly located (a central base station), hand-held (i.e., a hand-held portable data collection terminal or computer), or mounted to a vehicle (i.e., a forklift, delivery truck, etc.). Preferably, the interrogator **502** includes an RF transmitter, an RF receiver and an antenna. The RFID tag **504** receives the interrogating signal and transmits a response signal comprising encoded data back to the interrogator's receiver. The data encoded in the response signal may be as simple as 1-bit (the response indicates that the tag **504** is present or absent) or the data may be a serial stream providing a substantial amount of data to the interrogator **502**. Operating frequencies of such systems typically

range from 13 MHz to 6 GHZ.

Preferably, the RFID tag **504** may be placed on a metal or RF absorbing surface **506** without suffering significant degradation of its operating range. For example, the RFID tag **504** may be attached to the metal surface **506** of an object **508** such as an automobile, truck, trailer, cargo container, steel or aluminum warehouse pallet, etc. using a fastener such as an adhesive, double sided tape, screws, rivets, bolts, or the like. The RFID tag's RF transponder may be encoded with information relating to the goods or products **510** held by the object **508**. This information may, for example, be transmitted and written to the RF transponder's memory via the interrogator **502** and may include inventory information such as serial number, amount of goods, destination of goods, shipping instructions, etc. The interrogator **502** may query the RFID tag **504** to acquire this information when needed by users of the RFID system **500**.

Various modifications may be made in and to the above described embodiments without departing from the spirit and scope of the invention. For example, various modifications and changes may be made in the configuration of the RF transponder such as reconfiguration of the antenna geometry, battery arrangement, circuit chip construction, substrate material and geometry, and the like. Further, use of the RFID tag is directed to a wide variety of applications including, but not limited to, airline baggage (i.e., luggage, freight, and mail), postal service, manufacturing, inventory control, personnel security, and the like.

It is believed that the RFID tag of the present invention and many of its attendant advantages will be understood by the foregoing description, and it will be apparent that various changes may be made in the form, construction and arrangement of the components thereof without departing from the scope and spirit of the invention or without sacrificing all of its material advantages. The form herein before described being merely an explanatory embodiment thereof, it is the intention of the following claims to encompass and include such changes.

Claims

What is claimed is:

1. A RFID tag, comprising:

an RF transponder configured to communicate with an RFID system, said RF transponder including a dipole;

a base plate forming a conducting ground plane; and

a support attached to said base plate for retaining said RFID transponder so that the dipole is held at a distance from the conducting ground plane.

2. The RFID tag of claim 1, wherein said RF transponder further comprises:

a substrate mounted to said support and carrying the dipole; and

an RFID IC mounted to the substrate and coupled to the dipole.

3. The RFID tag of claim 2, wherein the RFID IC is packaged within a package mounted to the substrate and wherein the package interconnects the RFID IC to the dipole.

4. The RFID tag of claim 3, wherein the package is a small outline (SO) package.

5. The RFID tag of claim 1, wherein the dipole has a simple dipole structure.

6. The RFID tag of claim 1, wherein the dipole has a folded dipole structure.

7. The RFID tag of claim 1, wherein the dipole has a meander dipole structure.

8. The RFID tag of claim 1, wherein the impedance of the antenna is adjusted by modifying at least one of the width of the dipole, the length of the dipole, the distance between the dipole and the conducting ground plane, the size of the conducting ground plane.

9. The RFID tag of claim 1, wherein the dipole includes a tuning stub comprising parallel stub lines.

10. The RFID tag of claim 9, wherein the impedance of the antenna may be adjusted by modifying at least one of the width of the tuning stub, the length of the tuning stub, the distance of the tuning stub from the center of the dipole, and the edge to edge space between the stub lines.

11. The RFID tag of claim 1, wherein said base plate is made of metal.

12. The RFID tag of claim 11, wherein the metal is selected from the group consisting of aluminum, steel, brass, titanium, and copper.

13. The RFID tag of claim 1, wherein said base plate is made of a metallized material.

14. The RFID tag of claim 13, wherein the metallized material is a metallized plastic.

15. The RFID tag of claim 13, wherein the metallized material is a metallized mesh.

16. The RFID tag of claim 1, wherein a dimension of said base plate is approximately one half wavelength.

17. The RFID tag of claim 1, wherein said support holds said RF transponder above the conducting ground plane at a distance of approximately 7 percent to 11 percent of a wavelength.

18. The RFID tag of claim 1, wherein said support has a generally rectangular cross-section.

19. The RFID tag of claim 1, wherein said support has a generally trapezoidal cross-section.

20. The RFID tag of claim 1, wherein said support has a generally arcuate cross-section.

21. The RFID tag of claim 1, wherein said support has a generally triangular cross-section.

22. The RFID tag of claim 1, wherein said support has a generally polygonal cross-section.

23. The RFID tag of claim 1, wherein said support has a generally curvilinear cross-section.

24. The RFID tag of claim 1, wherein said support comprises a housing which encloses said RF transponder.

25. An RFID tag, comprising:

means for communicating information with an RFID system;

means for forming a conducting ground plane; and

means for holding said communicating means at a distance from the conducting ground plane.

26. A RFID system, comprising:

an interrogator including an RF transmitter, an RF receiver, and an antenna for communicating information via transmitted and received RF signals; and

an RFID tag including:

an RF transponder configured to communicate information with said interrogator, the RF transponder including a dipole;

a base plate forming a conducting ground plane; and

a support attached to the base plate for retaining the RF transponder so that the dipole is held at a distance from the conducting ground plane.

27. The RFID system of claim 26, wherein the RF transponder further comprises:

a substrate mounted to the support and carrying the dipole; and

an RFID IC mounted to the substrate and coupled to the dipole.

28. The RFID system of claim 27, wherein the RFID IC is packaged within a package mounted to the substrate and wherein the package interconnects the RFID IC to the dipole.

29. The RFID system of claim 28, wherein the package is a small outline (SO) package.

30. The RFID system of claim 26, wherein the antenna has a simple dipole structure.

31. The RFID system of claim 26, wherein the antenna has a folded dipole structure.

32. The RFID system of claim 26, wherein the antenna has a meander dipole structure.

33. The RFID system of claim 26, wherein the impedance of the antenna is adjusted by modifying at least one of the width of the dipole, the length of the dipole, the distance between the dipole and the conducting ground plane, the size of the conducting ground plane.

34. The RFID system of claim 26, wherein the antenna includes a tuning stub comprising parallel stub lines.

35. The RFID system of claim 34, wherein the impedance of the antenna may be adjusted by modifying at least one of the width of the tuning stub, the length of the tuning stub, the distance of the tuning stub from the center of the dipole, and the edge to edge space between the stub lines.

36. The RFID system of claim 26, wherein the base plate is made of metal.

37. The RFID system of claim 36, wherein the metal is selected from the group consisting of aluminum, steel, brass, titanium, and copper.

38. The RFID tag of claim 26, wherein said base plate is made of a metallized material.

39. The RFID tag of claim 38, wherein the metallized material is a metallized plastic.

40. The RFID tag of claim 38, wherein the metallized material is a metallized mesh.

41. The RFID tag of claim 26, wherein a dimension of said base plate is approximately one half wavelength.

42. The RFID tag of claim 26, wherein said support holds said RF transponder above the conducting ground plane at a distance of approximately 7 percent to 11 percent of a wavelength.

43. The RFID tag of claim 26, wherein said support has a generally rectangular cross-section.

44. The RFID tag of claim 26, wherein said support has a generally trapezoidal cross-section.

45. The RFID tag of claim 26, wherein said support has a generally arcuate cross-section.

46. The RFID tag of claim 26, wherein said support has a generally triangular cross-section.

47. The RFID tag of claim 26, wherein said support has a generally polygonal cross-section.

48. The RFID tag of claim 26, wherein said support has a generally curvilinear cross-section.

49. The RFID tag of claim 26, wherein said support comprises a housing which encloses said RF transponder.

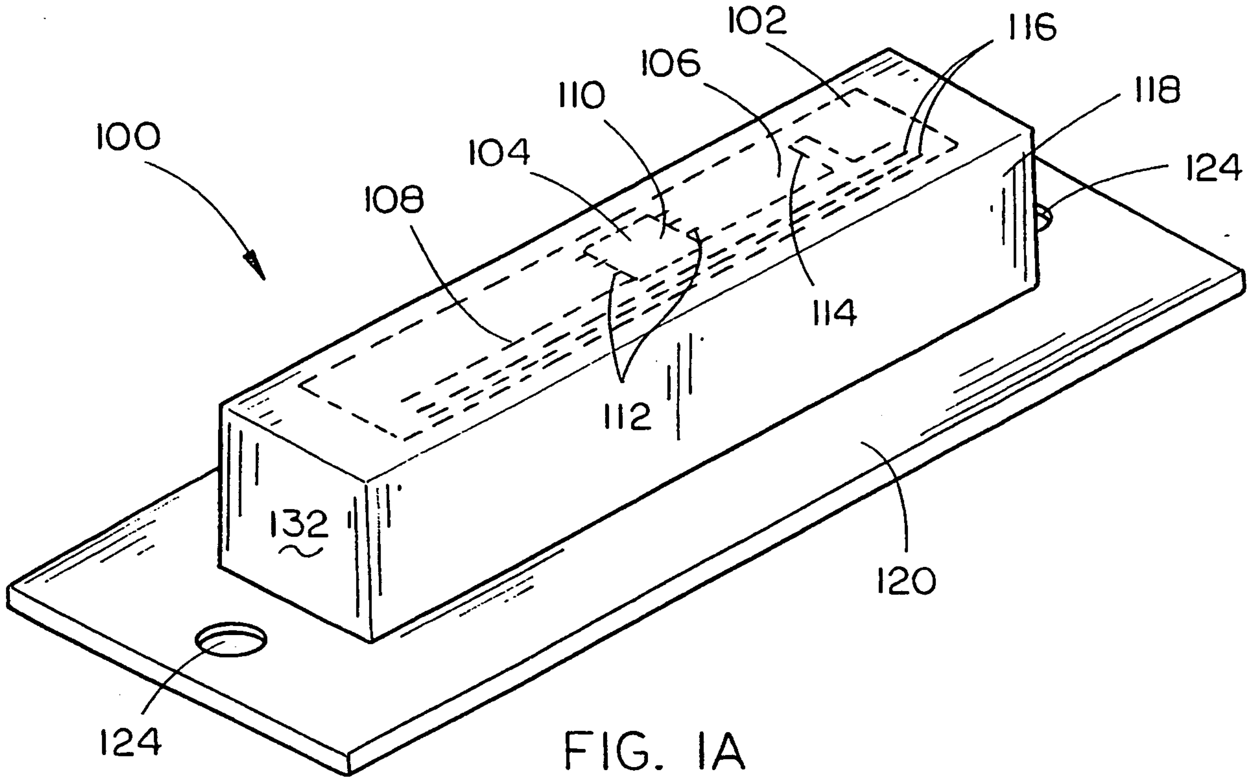
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FIG. 1A

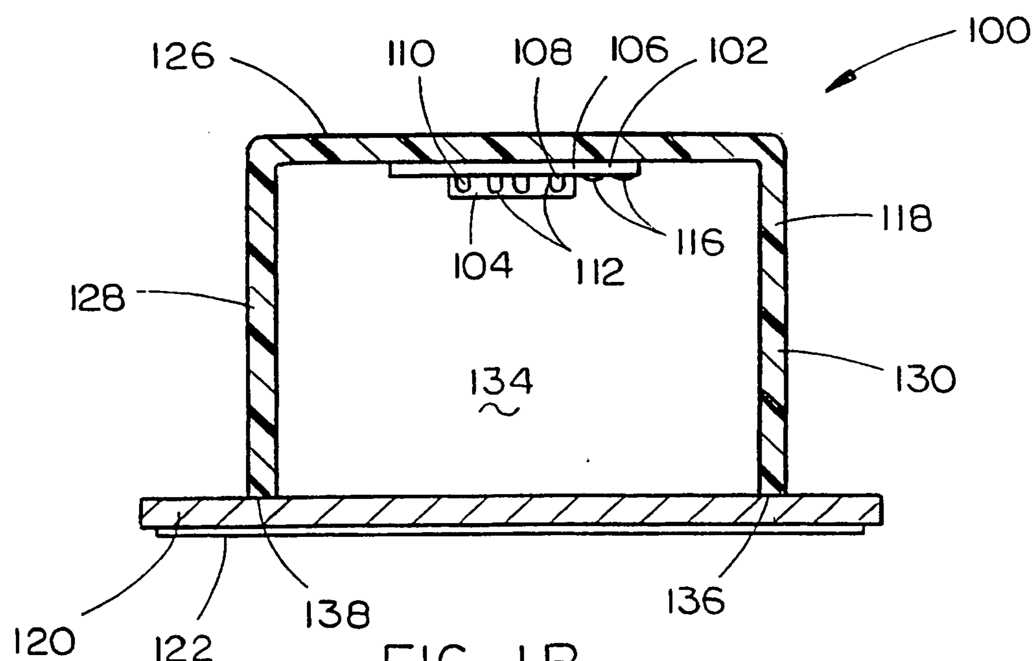
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FIG. 1B

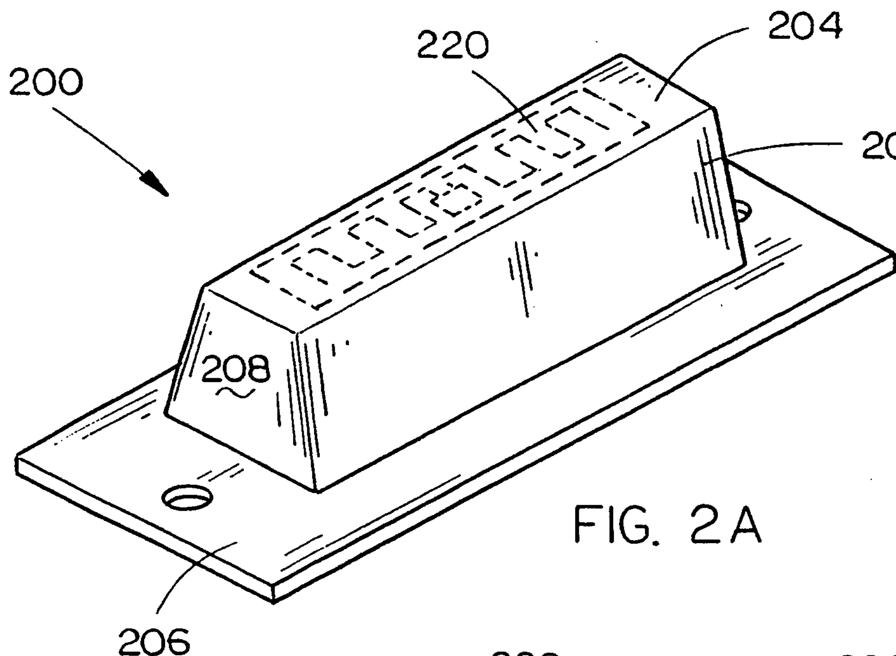

FIG. 2A

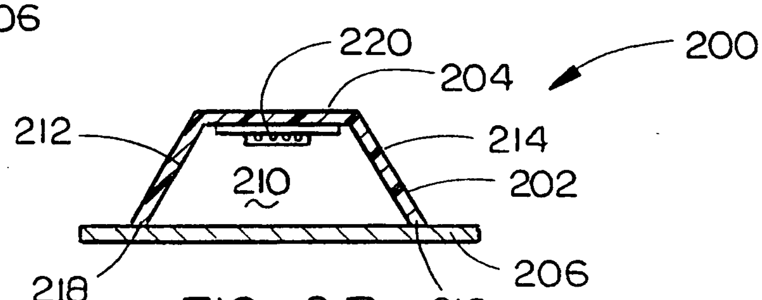

FIG. 2B

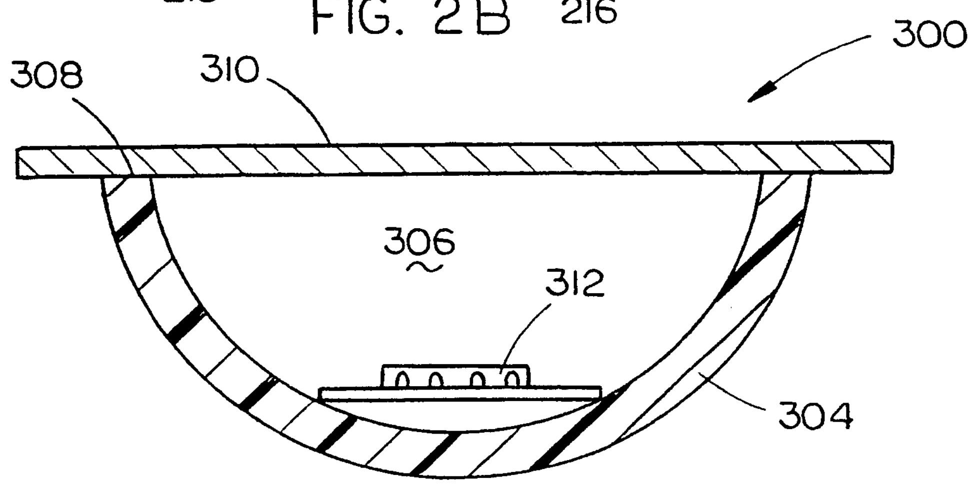

FIG. 3

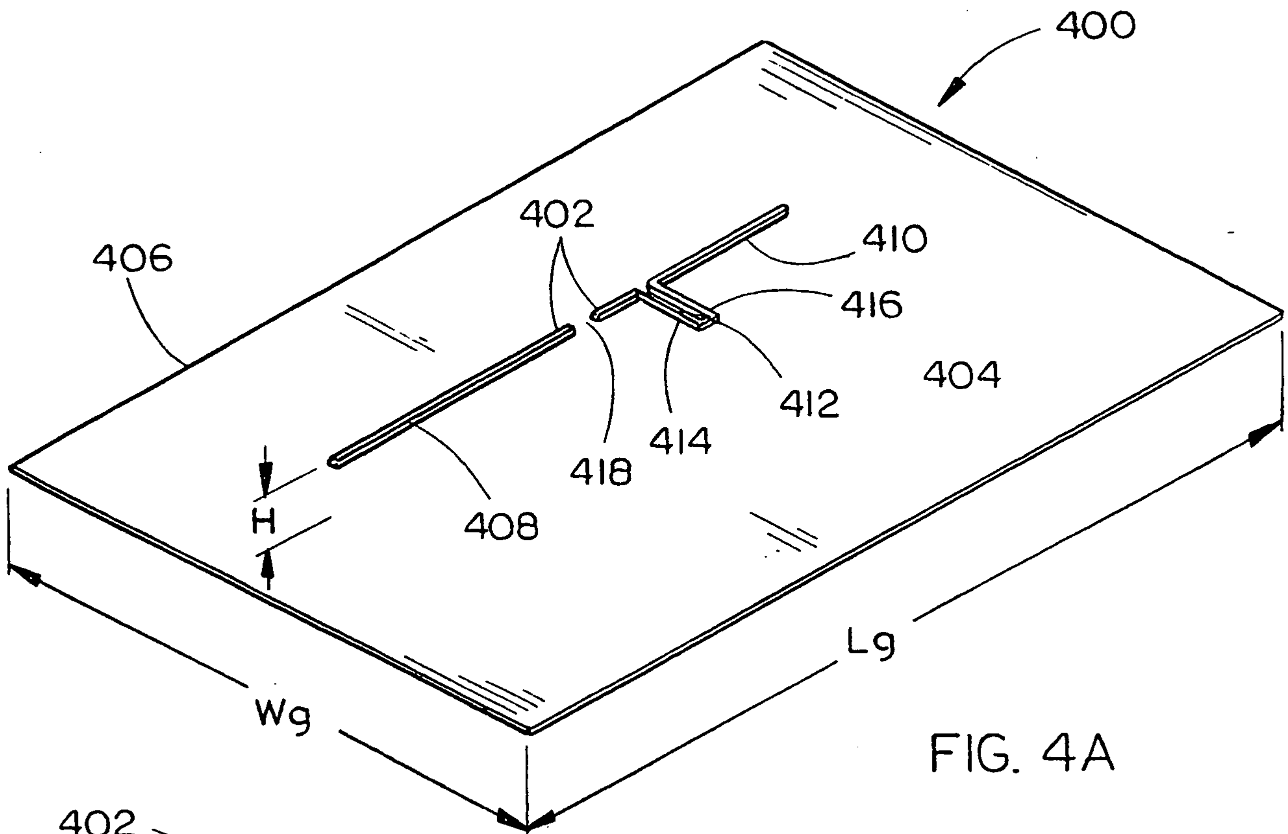

FIG. 4A

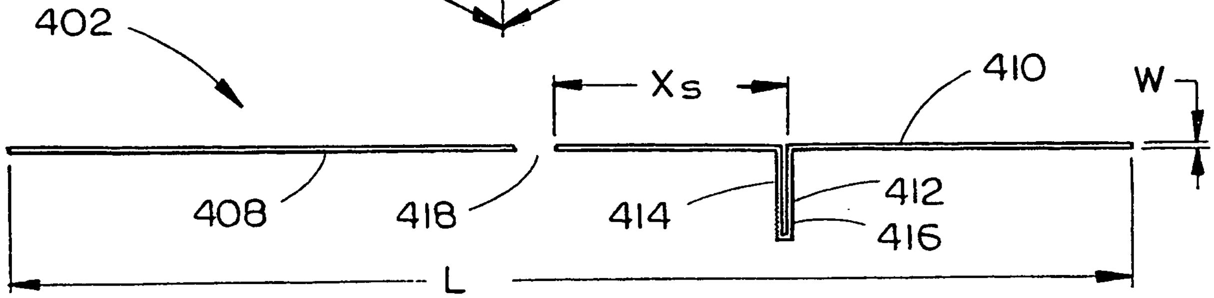

FIG. 4B

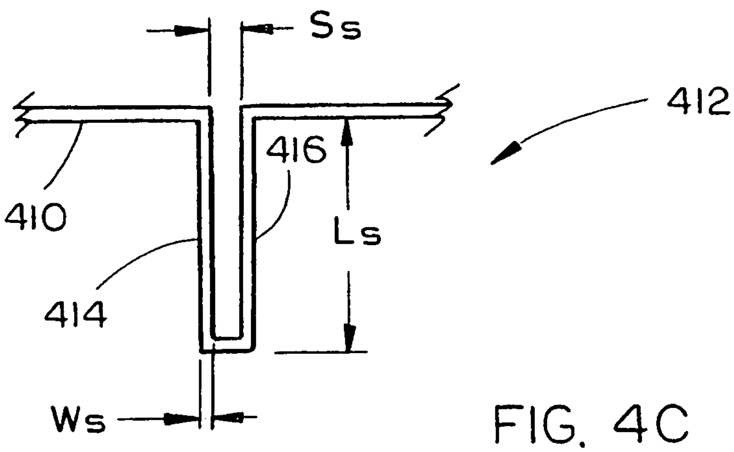

FIG. 4C

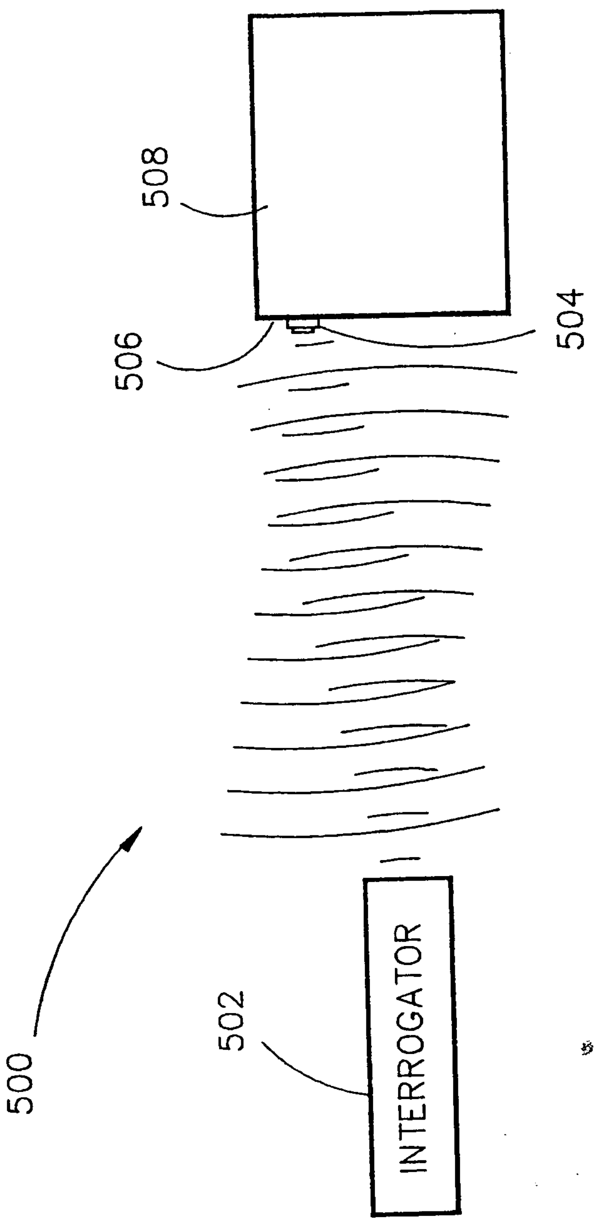

FIG. 5

INTERNATIONAL SEARCH REPORT

In. :ional Application No
PCT/US 99/23036

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G06K19/077 H01Q1/52 H01Q1/22 H01Q9/16 H01Q9/26
H01Q9/28

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G06K H01Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 590 589 A (TEXAS INSTRUMENTS HOLLAND ;TEXAS INSTRUMENTS INC (US)) 6 April 1994 (1994-04-06)	1,11-13, 18, 24-26, 36-38, 43,49
Y		2,5-9, 20-23, 27, 30-34, 45-48
A	abstract column 1, line 1 -column 3, line 26 figure 1 ---	14-17, 19, 39-42,44

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20 January 2000	27/01/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Jacobs, P

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INTERNATIONAL SEARCH REPORT

Int. ional Application No
PCT/US 99/23036

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5 528 222 A (COTEUS PAUL W ET AL) 18 June 1996 (1996-06-18) cited in the application	2,5-7, 27,30-32
A	abstract column 1, line 5 -column 2, line 32 column 3, line 9 -column 5, line 35 figures 2-6 ---	3,4,26, 28,29
Y	US 4 423 423 A (BUSH ELMER R) 27 December 1983 (1983-12-27)	8,9,33, 34
A	abstract column 3, line 44 -column 4, line 20 column 8, line 40 -column 9, line 11 figure 6 ---	10,35
Y	EP 0 769 765 A (SCHEIDT & BACHMANN GMBH) 23 April 1997 (1997-04-23)	20-23, 45-48
A	abstract column 3, line 43 -column 5, line 34 figures 1-7 -----	1,2,18, 19,44

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 99/23036

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0590589 A	06-04-1994	DE 69324093 D	29-04-1999
		DE 69324093 T	23-09-1999
		JP 6224609 A	12-08-1994
US 5528222 A	18-06-1996	AT 179270 T	15-05-1999
		CA 2153441 A	10-03-1996
		CN 1118910 A	20-03-1996
		DE 69509242 D	27-05-1999
		DE 69509242 T	04-11-1999
		WO 9607985 A	14-03-1996
		EP 0780007 A	25-06-1997
		EP 0855675 A	29-07-1998
		HU 76996 A	28-01-1998
		JP 8088586 A	02-04-1996
		PL 318977 A	21-07-1997
		SG 46938 A	20-03-1998
		ZA 9507078 A	11-03-1996
US 4423423 A	27-12-1983	NONE	
EP 0769765 A	23-04-1997	NONE	